RESEARCH

The Effect of Higher Temperatures on Cotton Lint Yield Production and Fiber Quality

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ABSTRACT

An optimal temperature range exists for cotton (*Gossypium hirsutum* L.). When Mississippi Delta cotton experiences temperatures above the upper threshold, as can occur during the summer, it is not entirely clear what growth parameters are affected by the heat. The objectives of this study were to document differences in agronomic and physiological performance for two cotton genotypes (SureGrow 125 and SureGrow 125BR) when grown under an ambient temperature control and a warm temperature regime (about 1°C warmer). Field studies were conducted from 2003 through 2005. White bloom counts, nodes above white bloom (NAWB) data, dry matter partitioning data, lint yield, yield components, and fiber quality data were collected. Genotypes responded similarly to the temperature regimes. Warmer temperatures resulted in lower NAWB data, indicating a slightly advanced crop maturity. In two out of three years, the lint yield from the warm regime was 10% lower than that of the control. This reduction was primarily caused by a 6% smaller boll mass, with 7% fewer seed produced per boll in the warm regime. Fiber produced in the warm temperature regime was consistently 3% stronger than fiber in the control treatment. When temperatures become too hot, ovule fertilization may be compromised, leading to fewer seeds produced per boll, smaller boll masses, and ultimately, lint yield reductions.

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Abbreviations: AFIS, Advanced Fiber Information System; Chl, chlorophyll; DAP, days after planting; F_v/F_m, variable Chl fluorescence/maximum fluorescence ratio; LAI, leaf area index; NAWB, nodes above white bloom; PPFD, photosynthetic photon flux density.

Cotton (*Gossypium hirsutum* L.) is of subtropical, semiarid origin and is accustomed to warm, dry conditions (Lee, 1984). As with all plant species, an optimum temperature range exists for cotton growth, above and below which growth is depressed. Burke et al. (1988) defined the optimal temperature range or "thermal kinetic window" based on enzyme kinetics for cotton as between 23.5 and 32°C. They found a linear relationship between biomass production and the length of time the foliage temperature was within that optimum range. However, it is not uncommon for ambient air temperatures to exceed that upper threshold during the afternoon hours of July and August in the Mississippi Delta (Boykin et al., 1995). Most previous research on cotton response to higher temperatures has consisted primarily of artificial growth environment studies (growth chambers and greenhouses) (Reddy et al., 1991, 1992, 1999) or studies correlating cotton growth across multiple locations and years with the local weather data (Krieg, 2002; Meredith, 2002, 2005). In these artificial growth environments, Reddy et al. (1992) reported decreased reproductive dry matter as temperatures increased above 30°C and

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reduced flower retention with increased exposure to 40°C. Boll maturation period and boll size also decreased with higher temperatures, and fiber length was reduced (Reddy et al., 1999). Krieg (2002) reported that warmer night temperatures increased the fiber micronaire, and Meredith (2005) found that higher temperatures resulted in shorter fibers. While useful, these studies do not provide complete insight into how cotton's growth will respond to periods of higher temperatures because cotton grown in artificial environments sometimes does not behave like field-grown cotton (Carmi and Shalhevet, 1983), and the correlative studies do not completely isolate the temperature effect from other factors. For instance, higher temperatures often coincide with periods of high sunlight and/or periods of low precipitation (Boykin et al., 1995).

Gipson and Joham (1968a,b, 1969), using chambers equipped with either gas fired furnaces or air conditioners in the Texas Southern High Plains, investigated the influence night temperatures in the range of 5 to 25°C have on cotton production under field conditions. Night temperatures are often easier to associate with crop productivity because high night temperatures can sometimes be separated from periods of high sunlight. They found that boll development slowed and the rate and amount of cellulose synthesis was reduced as night temperatures decreased (Gipson and Joham, 1968a,b). Maximum fiber elongation rates were also obtained with night temperatures ≥21.1°C (Gipson and Joham, 1969). A concern with the chambers used in these studies, however, is how gas flow and exchange within the canopies would be affected by the chamber walls relative to that in a natural field environment.

Hence, uncertainty remains as to how completely information from these studies will translate into field performance in the southeastern and mid-southern parts of the U.S. cotton production belt, which are more humid environments than that of the semiarid Texas Southern High Plains. The increased humidity impacts the plants ability to cool itself through evapotranspiration and could potentially alter a temperature response. Therefore, the objectives of this study were to compare the agronomic and physiological field performance of two cotton cultivars under both the ambient temperature regime and a temperature regime a few degrees warmer than ambient. Using a transgenic cotton cultivar paired with its conventional recurrent parent cultivar will also provide insight into whether transgenic lines behave differently than conventional lines to different temperature regimes.

MATERIALS AND METHODS

Field studies were conducted near Stoneville, MS, during the 2003–2005 growing seasons to test the effect warmer temperatures have on the agronomic and physiological traits determining lint yield and fiber quality. Field plots were established on a highly productive Bosket fine sandy loam (fine-loamy, mixed, active, thermic Mollic Hapludalf) soil in a randomized complete block design with two temperature regimes and two cotton cultivars arranged factorially. Five replications were used. The two temperatures regimes were the ambient air temperature (Ambient) and a regime that was approximately 1°C warmer than ambient (Warm). Genotypes used in this study were 'SureGrow 125' and its transgenic counterpart 'SureGrow 125BR' (SG 125 and SG 125BR; Delta and Pine Land Co., Scott, MS). SG 125BR contains both the Bt gene that produces an endotoxin (Cry1Ac) lethal to certain lepidopteran insects and a gene that conveys resistance to the herbicide glyphosate.

The plots were planted on 21 Apr. 2003, 22 Apr. 2004, and 18 Apr. 2005 and consisted of four rows 7.62 m long with a 1-m row spacing. Initially, the plots were overseeded and subsequently hand thinned to a uniform population density of 9 plants m^{-1} of row or approximately 97,000 plants ha^{-1} when the plants were at the second or third true leaf stage. The experimental area received 112 kg ha^{-1} N in a preplant application each year. It was furrowed irrigated as needed each year to minimize moisture stress. Recommended insect and weed control were used throughout each growing season as needed.

The warm temperature regime was generated by placing 30-cm × 6-m Redi-Heat propagation mats (Phytotronics, Inc., Earth City, MO) between the rows on 30-cm-tall × 30-cm-wide × 6-m-long wooden racks. Mounting the mats on the wooden racks positioned the mats closer to the reproductive structures and allowed for furrow irrigation in those rows. Four mats were used per plot. Power to the mats was controlled with Redi-Heat RFT4 thermostats (Phytotronics, Inc.) that operated through a temperature range of 4 to 38°C but were set so that power supplied to the mats would not cut off until 38°C. Sensors for the thermostats were mounted inside 30-cm-long, 5-cm-diam. open-ended white polyvinylchloride tubes, which were positioned 76 cm above the ground in the crop canopy and within a plot row. One thermostat and one thermostat sensor were used per plot. The wooden racks, propagation mats, and thermostats were placed in the plots during the first week of July each year. Electrical power was supplied to the mats from 3 July through 1 Sept. 2003, from 6 July through 10 Sept. 2004, and from 1 July through 5 Sept. 2005. The period during which power was supplied to the heating mats roughly corresponded to the stages of growth from early bloom through boll filling.

Canopy air temperatures were monitored in all plots of reps 1 through 3 using Hobo H8 Pro Temp (Onset Computer Corp., Bourne, MA) data loggers. These temperature sensor–equipped data loggers were mounted inside solar radiation shields (Onset Computer Corp.) and positioned in the crop canopy on metal poles approximately 1 m off the ground. Temperature measurements were collected every 30 min for the same period of time as for when the electricity was supplied to the heating mats.

Dry matter partitioning data were collected by harvesting the aboveground portion of plants from 0.3 m of row in each plot and separating the plants into the component parts of leaves, stems and petioles, squares, and blooms and bolls. Leaf area was determined by passing the leaves through a LI-3100 leaf area meter (LI-COR, Lincoln, NE), and the main stem nodes were counted. Plant part samples were dried for at least 48 h at 60°C and the dry weights recorded. Dry matter harvest

were conducted at 72 and 112 d after planting (DAP) in 2003, 76, and 109 DAP in 2004, and 79 and 112 DAP in 2005. The early dry matter harvests approximately corresponded to an early bloom stage and were collected shortly before or immediately after initiation of the warm temperature regime. The second dry matter harvests roughly correspond to a cutout harvest date. Cutout refers to a period of slowing vegetative growth and flowering because of assimilate diversion to feed the demand of the existing boll load.

The number of white blooms (blooms at anthesis) per plot were counted on a weekly basis to document the blooming rate throughout the growing seasons. These counts were taken on one of the inner plot rows and were initiated shortly after the imposition of the temperature treatments and continued until the production of blooms had almost stopped. The number of main-stem nodes above a sympodial branch that had a white bloom at the first branch fruiting position (nodes above white bloom [NAWB]) were also counted weekly on three plants per plot to document the progressive reproductive development up the main stem as well as crop maturity.

Dark-adapted chlorophyll (Chl) variable fluorescence/maximal fluorescence (F_v/F_m) ratios were measured on two leaves per plot using a Hansatech Fluorescence Monitoring System (Hansatech Instruments Ltd. Norfolk, UK). The youngest fully expanded, disease-free, fully sunlit leaves in each plot were used and were allowed to dark adapt for at least 15 min before measurement. In 2003 and 2004, immediately after the dark-adapted Fv/Fm readings, the leaves were exposed and acclimated to 650 μmol m^{-2} s^{-1} photosynthetic photon flux density (PPFD) for 90 sec. After this period of acclimation, light-adapted Chl fluorescence (F_s, steady state fluorescence yield; and F_m', light-adapted fluorescence maximum) were measured at 650 μmol m^{-2} s^{-1} PPFD. A saturation pulse of 9,000 μmol m^{-2} s^{-1} PPFD was used to for all Chl fluorescence measurements. From these light-adapted values, the quantum efficiency of photosystem II and electron transport rate were determined. In 2005 gas exchange was measured on these leaves before any fluorescence measurements using a CI-310 portable photosynthesis system (CID, Inc., Camas, WA). All measurements were taken with the leaves oriented perpendicular to the sun with the PPFD reaching the leaf surface ≥1600 μmol m^{-2} s^{-1}. Light-acclimated fluorescence was measured on these leaves at ≥1600 μmol m^{-2} s^{-1} PPFD immediately following the gas exchange readings using the Chl fluorescence module on the CI-310. Leaves were then dark adapted for the 15-min period followed by dark-adapted F_v/F_m measurements as in the previous years.

Yield was determined by hand harvesting the 4.6-m center section of row from one of the two inner plot rows. The number of bolls harvested per plot was counted each year. Boll mass was determined by dividing the total seed cotton harvested per plot by the total number of bolls harvested per plot. Lint yield and lint percentage were determined by ginning the seed cotton on a ten-saw laboratory gin. Average seed mass was determined from 100 non-delinted seeds per plot. The number of seed per bolls was calculated from the total seed weight per plot after ginning the seed cotton, the seed mass, and the number of bolls harvested per plot. One sample of the resulting lint from each plot was then sent to Starlab (Knoxville, TN) for fiber quality analyses. Fiber strength was determined by stelometer. Span lengths were measured with a digital fibrograph. Fiber maturity, wall thickness, and perimeter were calculated from arealometer measurements. Length uniformity, Rd (reflectance %), and +b (yellowness) were determined by high volume instrumentation (HVI) classification. In 2004 and 2005, a second lint sample was also tested for fiber quality traits using the Advanced Fiber Information System (AFIS) (Zellweger Uster Inc., Knoxville, TN).

Statistical analyses were performed by analysis of variance (PROC MIXED; SAS Institute, 1996). For traits where year interacted with treatments and the environmental effects associated with year were identified, the results were presented by year. When the treatment or genotype differences for a trait were consistent across years, the treatment or genotype means were averaged across years, and the year interactions with treatment or genotype were considered a random source of error. When statistically significant and meaningful interactions were not detected, treatment means were averaged across genotypes, and genotype means were averaged across treatments. Means were separated using a protected LSD at the $P \leq 0.05$ level.

Table 1. Monthly weather summary for 2003 to 2005 at Stoneville, MS.†

Month	2003	2004	2005
		Precipitation	
		cm	
April	9.6	10.5	11.5
May	6.5	18.4	5.4
June	18.5	31.6	1.9
July	6.2	7.8	10.6
August	3.9	5.5	12.6
September	12.5	0.1	17.9
October	10.1	18.1	0.0
		Thermal units‡	
April	114	107	93
May	245	249	214
June	288	317	326
July	375	362	383
August	392	315	415
September	248	275	325
October	127	203	123
		Solar radiation	
		MJ m^{-2}	
April	474	671	633
May	482	663	714
June	656	657	721
July	692	672	636
August	641	657	677
September	598	571	566
October	476	380	535

†All observations made by NOAA, Mid-South Agric. Weather Service, and Delta Research and Extension Center Weather, Stoneville, MS.

‡[(Max. temp. + Min. temp.)/2] – 15.5°C.

RESULTS AND DISCUSSION

The years 2003 through 2005 offered three distinctive years in terms of weather for conducting the research (Table 1). Both 2003 and 2004 tended to have milder temperatures with more precipitation during the first half of the growing season. The growing season was warmer from June through September in 2005, with greater August and September precipitation due to two tropical systems (Hurricane Katrina in late August and Hurricane Rita in mid-September).

The heating mats were only moderately successful in elevating the temperature of the warm temperature regime above that of the ambient air because there was nothing keeping the heat in the target rows from radiating out to the surrounding atmosphere (Table 2). The difference in daily average temperature at a 1-m height averaged across the entire heating period ranged from 0.5 to 0.8°C depending on the year. While this appears to be a minimal temperature differential, it was present continually throughout the period. In addition, the warm temperature treatment was more effective once the canopy closure had been obtained, with the temperature differentials typically of the 1 to 1.5°C range (data not shown). Comparing the different growing seasons, the warm temperature regime produced temperatures exceeding 35°C for three additional days relative to the ambient regime in 2003 and 2004, but only one additional day in 2005. The warmer summer of 2005 produced multiple days where the maximum air temperature exceed 38°C, triggering the thermostats to temporarily shutoff power to the heating mats and thereby also temporarily removing the temperature treatments.

Few dry matter partitioning differences were detected between the temperature regimes, and when they were detected, they were not consistent across years. Therefore, these data were presented for each individual year (Table 3). The only instance when temperature regime means were significantly different occurred in 2005 when plants grown under the warm temperature regime had a 16% greater harvest index than plants grown the control ambient air (0.441 vs. 0.380). A numeric trend for these differences was also observed in the other years, but the differences were not close to being statistically different. One explanation for the greater harvest index under warmer temperatures is that warmer temperatures may quicken the pace of crop maturation.

No temperature differences were detected in the blooming rate on any of the dates when blooms were counted for any year of this study (data not shown). Temperature treatment differences were detected in the NAWB data, although this was not the most consistent of phenomenon, with differences detected on only one date in 2003, but on two dates in both 2004 and 2005 (Fig. 1). Whenever these significant temperature differences were detected plants from the ambient air temperature regime had a greater NAWB number than the warmer regime,

Table 2. Average canopy air temperatures (± SE) measured at approximately a 1-m height during the months of July and August as affected by two canopy air temperature (ambient and warm) treatments, averaged across two genotypes for the years 2003 to 2005.

Year	Temp. regime	Average temp.	Average max. temp.	Average min. temp.	Days ≥35°C
		———— °C ————			d
2003	Ambient	26.8 (± 0.02)	33.3 (± 0.07)	21.7 (± 0.06)	15.7 (± 1.1)
	Warm	27.3 (± 0.05)	33.7 (± 0.12)	22.3 (± 0.04)	18.4 (± 1.4)
2004	Ambient	25.2(± 0.03)	32.1 (± 0.10)	20.0 (± 0.14)	8.9 (± 1.3)
	Warm	26.0 (± 0.06)	32.8 (± 0.12)	20.7 (± 0.07)	11.7 (± 2.0)
2005	Ambient	27.2 (± 0.02)	33.7 (± 0.06)	22.1 (± 0.03)	21.4 (± 0.7)
	Warm	27.8 (± 0.04)	34.1 (± 0.06)	22.9 (± 0.05)	22.6 (± 0.6)

Table 3. Cotton growth, development, and dry matter partitioning parameters as affected by two canopy air temperature (ambient and warm) regimes at cutout, averaged across two genotypes for the years 2003 to 2005.

Year	Temp. regime	Height	Main stem nodes	Leaf area index	Specific leaf weight	Vegetative weight	Reproductive weight	Harvest index†
		cm	nodes plant^{-1}			———— g m^{-2} ————		
2003	Ambient	105	19.4	3.58	48.8	466	518	0.526
	Warm	102	19.2	3.75	50.2	506	614	0.543
	LSD (0.05)	ns‡	ns	ns	ns	ns	ns	ns
	P > *F*	0.29	0.58	0.66	0.49	0.44	0.19	0.43
2004	Ambient	116	20.3	3.36	52.4	525	267	0.327
	Warm	112	19.6	3.10	57.0	506	288	0.353
	LSD (0.05)	ns	ns	ns	ns	ns	ns	ns
	P > *F*	0.36	0.17	0.55	0.09	0.78	0.77	0.5
2005	Ambient	125	21.0	3.85	53.6	623	388	0.380
	Warm	120	21.0	4.04	51.5	590	481	0.441
	LSD (0.05)	ns	ns	ns	ns	ns	ns	0.05
	P > *F*	0.44	0.98	0.71	0.13	0.73	0.31	0.01

†Harvest index = reproductive dry weight/total aboveground dry weight.

‡ns, not significantly different at the 0.05 level.

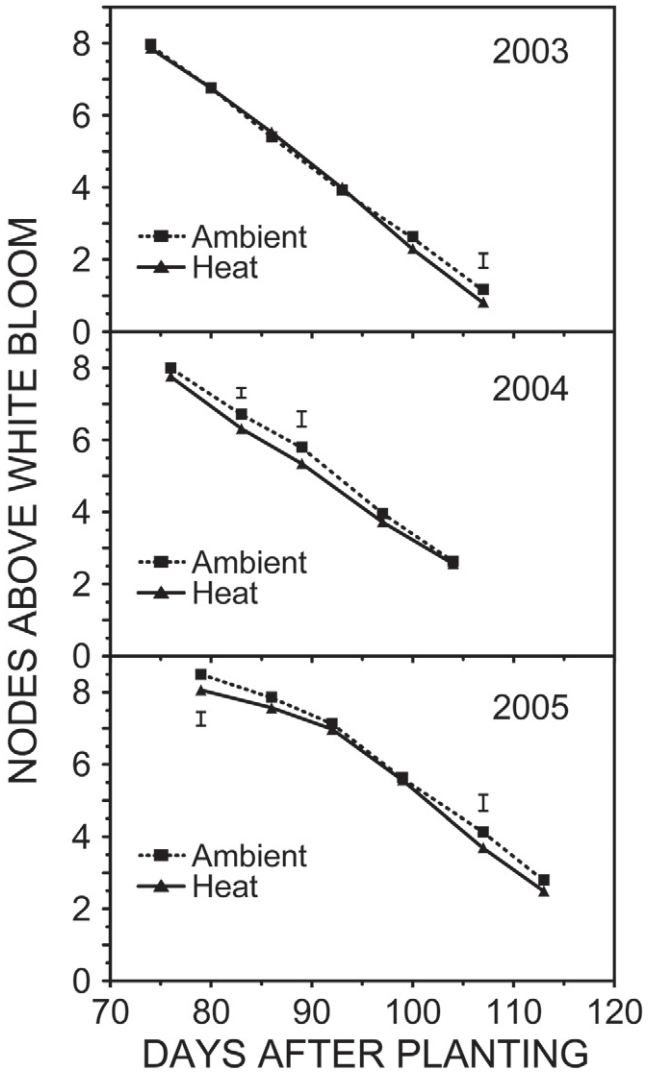

Figure 1. Number of main-stem nodes of cotton above a sympodial branch with a first-position white bloom (bloom at anthesis) at various times throughout the 2003 and 2005 growing seasons in plots of two different temperature regimes. These temperature regimes means were averaged across two cotton cultivars (SureGrow 125 and SureGrow 125BR). Vertical bars denote LSD values at the 0.05 level and are present only when the differences between temperature regimes are statistically significant at the 0.05 level.

indicating that plants in the warmer regimen were slightly earlier in maturity than the ambient air plants. The flowering interval between position 1 fruit on successive main stem nodes is approximately 3 d (Bednarz and Nichols, 2005), and NAWB differences between temperature regimes is always less than one node. Therefore, the plants in the warm temperature regime would only be 3 d or less earlier in maturity than the control plants.

Few leaf photosynthetic differences were detected between temperature regimes (Table 4). Neither the CO_2 exchange rate nor any of the Chl fluorescence parameters were significantly altered by the different temperature regimes. Leaves from the warm temperature regime did operate with 20% lower water use efficiency compare with leaves from the control plants in 2005. Perry et al. (1983) had previously reported that net photosynthesis declined with increasing temperatures primarily because the higher temperatures increased the rate of photorespiration. That response was not observed in this study perhaps because of the small temperature spread between the two temperature regimes of this study.

The lint yield response to the two temperature regimes was variable across the years; therefore, the data are presented by year. In both 2003 and 2004, warmer temperatures reduced the lint yield produced by an average of 10% relative to plots grown under the ambient air regime (Table 5). Temperature had no effect on lint yield in 2005. The number of bolls produced per unit ground area, generally the principle yield component determining yield, was not affected by varying the growth temperature. However, in 2004 both lint percentage (3%) and boll mass (6%) were reduced in the warm regime relative to the ambient air regime. Boll mass in the warm regime was also numerically reduced in the other 2 yr of the study as well. Because seed mass did not differ between temperature regimes, a reduced number of seed per boll (7%) under the warmer temperatures led to the boll mass reduction observed in the warm regime. Therefore, it appears that reduced boll mass because of fewer seed produced per boll were the principle yield components leading to the lint

Table 4. Cotton leaf gas exchange and chlorophyll parameters as affected by two canopy temperature regimes (ambient and warm) averaged across two genotypes and the years 2003 through 2005.

Temp. regime	CO_2 exchange rate†	Water use efficiency	Dark-adapted F_v/F_m‡	Photosystem II quantum efficiency (ϕ_{II})§	Electron transport rate	Quenching coefficients	
						Photochemical	Nonphotochemical
	μmol m^{-2} s^{-1}	μmol CO_2 mol H_2O^{-1}			μmol m^{-2} s^{-1}		
Ambient	22.7	9.6	0.793	0.367	117	1.265	0.870
Warm	22.9	7.6	0.787	0.371	111	1.058	0.884
LSD (0.05)	ns¶	1.6	ns	ns	ns	ns	ns
P > *F*	0.95	0.02	0.28	0.84	0.56	0.50	0.61

†CO_2 exchange rate and water use efficiency were only measured in 2005.

‡F_v/F_m, variable Chl fluorescence/maximum fluorescence ratio

§Photosystem II quantum efficiency and electron transport rate measured at 650 μmol m^{-2} s^{-1} photosynthetic photon flux density (PPFD) in 2003 through 2004 but at ³1600 μmol m^{-2} s^{-1} PPFD in 2005.

¶ns, not significantly different at the 0.05 level.

yield reduction caused by warmer temperatures. The lack of a temperature yield response in 2005 may be because the warmer overall conditions in 2005 (Table 1) pushed both the ambient and warm temperature regimes outside the optimum range for cotton growth. Any potential negative impacts that the two tropical systems had on yield in 2005 was not quantified but also cannot be discounted.

Most fiber quality traits were not affected by varying the temperature regimes (Tables 6 and 7). The exceptions to this generalization were fiber strength (T1), fiber maturity, and reflectance percentage. Fiber produced in the warm temperature regime was 3% stronger than fiber from the ambient regime. Although micronaire was not affected by the different temperatures, one of its components, fiber maturity, was 2% greater with the warmer temperatures. The other component of micronaire, fiber perimeter was not affected. The reflectance percentage (Rd) for the lint from the warm regime was 1% lower than that from the ambient regime. None of these fiber quality alterations would elicit either a premium or discount in the lint pricing structure.

Even though SG 125 and SG 125BR were genetically very similar, some minor fiber quality differences were detected between the genotypes (Tables 7 and 8). Fiber produced by SG 125BR was generally shorter than that produced by SG 125. Stelometer 2.5% span length was 2% shorter for SG 125BR, while AFIS mean length and 2.5% span lengths were both 3% shorter. The reflectance percentage for SG 125BR was also 1% greater than that of SG 125. Similar to the temperature response, these minor fiber quality differences would not alter the price received for the lint for either of these genotypes.

The results from this research offer a field confirmation of some of the findings from the various controlled environment studies investigating the negative response of cotton to higher temperatures. There was also an apparent negative association between the number of days exposed to maximum temperature ≥35°C and yield (Tables 2 and 5), which supports the work of Burke et al. (1988) that temperatures above 32°C are detrimental to cotton. The lack of a temperature effect on reproductive dry matter accumulated by cutout contrasts with the results reported by Reddy et al. (1991, 1992) that temperatures above 30°C reduced total reproductive weights. However, the lint yield reduction observed with warmer temperatures indicates that reproductive growth was indeed negatively impacted. This apparent discrepancy may be explained by the use of different genotypes among the studies or that the temperature differential generated in this field environment was not as large as that produced in the artificial environment studies. The slightly reduced NAWB data found in the warm regime complement the reduced boll maturation period under high temperatures reported by both Reddy et al. (1999) and Gipson and Joham (1968a) to demonstrate how higher temperature can advance maturity in cotton.

Lint yield reductions because of smaller boll masses produced when the cotton was grown under the warm temperature regime (Table 5) are consistent with the findings of Reddy et al. (1999), who also reported decreased boll weights as temperature increased. Few seeds produced per boll under the warm temperature regime led to the reduced boll mass and indicates that one of the primary detrimental influences that higher temperature has on lint production may be through a disruption of ovule fertilization. Supporting this conclusion is the work of Meyer (1969), who reported that viability of cotton pollen can decrease as temperatures increase.

Few fiber quality traits were altered by the elevated temperatures. The lack of a temperature effect on fiber length contrasts with the finding of both Reddy et al. (1999) and Meredith (2005), who reported that higher temperatures produced shorter fiber lengths. A larger temperature differential than could be produced by the methodology used in this study may be necessary to generate observable differences in fiber length. Although warmer temperatures did not produce statistically greater fiber micronaire as had been previously reported by Krieg (2002), lint from the warm temperature regime did have statistically higher fiber maturity. Because fiber maturity is a component of micronaire, this increased fiber maturity tends to support the findings of increased micronaire with higher temperatures (Krieg, 2002). The slightly stronger fiber produced by the warm temperature regime appears to be new information. Because fewer seeds were produced per

Table 5. Cotton lint yield and yield components as affect by two canopy temperature regimes (ambient and warm), averaged across two genotypes and for the years 2003 through 2005.

Year	Temp. regime	Lint yield	Lint %	Boll no.	Boll mass	Seed mass	Lint index	Seed no.
		kg ha^{-1}	%	boll m^{-2}	g boll^{-1}	—— mg seed^{-1} ——		seed boll^{-1}
2003	Ambient	1437	37.8	86	4.49	97	59	23
	Warm	1348	37.8	83	4.36	96	59	21
	LSD (0.05)	88	ns†	ns	ns	ns	ns	1
	P > *F*	0.05	0.89	0.46	0.21	0.88	0.80	0.01
2004	Ambient	1486	41.5	83	4.37	95	68	21
	Warm	1286	40.3	79	4.11	95	65	20
	LSD (0.05)	138	0.9	ns	0.21	ns	ns	ns
	P > *F*	0.01	0.02	0.21	0.02	0.87	0.06	0.08
2005	Ambient	1246	38.8	76	3.96	87	55	25
	Warm	1253	38.8	77	3.88	90	57	23
	LSD (0.05)	ns	ns	ns	ns	ns	ns	1
	P > *F*	0.85	0.95	0.71	0.17	0.06	0.19	0.01

†ns, not significantly different at the 0.05 level.

boll, the source-to-sink ratio for each ovule in the warm regime may have been altered such that more assimilate was available for the developing fibers on each individual ovule. Previous research has demonstrated that greater fiber strength is produced under growth conditions that enriched the potential amount of photosynthetic assimilates available to the developing boll load (Pettigrew, 1995, 2001).

In conclusion, whenever air temperatures become excessively high during the blooming and boll-filling periods, a loss in lint yield can be sustained. The loss initially manifests itself as a reduction in boll size because of fewer seeds per boll. The tradeoff is that the fiber produced is stronger. However, this minor improvement in fiber strength is not be sufficient to elicit a price premium and therefore could not offset the economic loss sustained from the loss in lint production.

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Table 6. Cotton fiber quality determined by stelometer, arealometer, and high volume instrumentation (HVI) as affected by two canopy temperature regimes (ambient and warm) averaged across two genotypes and the years 2003 through 2005.

Temp. regime	Fiber elongation (E1)†	Fiber strength (T1)	Span length		Micronaire	Fiber maturity‡	Fiber perimeter	Length uniformity§	Rd	+b
			2.5%	50%						
	%	kN m kg^{-1}	— cm—			%	μm	—%—		
Ambient	8.4	178	2.83	1.38	4.46	77.6	53.4	83.1	70.1	7.39
Warm	8.2	183	2.82	1.36	4.53	79.3	52.7	82.9	69.2	7.48
LSD (0.05)	ns¶	3	ns	ns	ns	1.5	ns	ns	0.8	ns
P > *F*	0.23	0.01	0.29	0.26	0.25	0.03	0.20	0.34	0.03	0.72

†Fiber elongation, strength, span lengths, and micronaire were determined by stelometer.

‡Fiber maturity and perimeter were determined by arealometer.

§Length uniformity, Rd (reflectance %), and +b (yellowness) were determined by HVI classification.

¶Not significantly different at the 0.05 level.

Table 7. Cotton fiber quality measured using the Advanced Fiber Information System (AFIS) as affected by two canopy temperature regimes (ambient or warm) or two genotypes. Temperature means were averaged across genotypes and the years 2004 through 2005. Genotype means were averaged across temperatures and the years 2004 through 2005.

Genotype	Temp. regime	Mean length (weight)	2.5% span length	Short fiber content		Fineness	Maturity ratio	Neps	Seed coat fragments
				Weight	Number				
		—cm—		—%—		mTex			
	Ambient	2.48	3.57	6.9	20.0	174	0.90	132	8.05
	Warm	2.47	3.55	7.0	20.1	176	0.91	141	9.35
	LSD (0.05)	ns†	ns	ns	ns	ns	ns	ns	ns
	P > *F*	0.61	0.47	0.75	0.89	0.39	0.10	0.20	0.11
SureGrow 125		2.51	3.61	6.8	20.0	174	0.91	139	9.25
SureGrow 125BR		2.44	3.51	7.1	20.1	176	0.91	135	8.15
LSD (0.05)		0.04	0.04	ns	ns	ns	ns	ns	ns
P > *F*		0.01	0.01	0.40	0.94	0.27	0.99	0.56	0.18

†ns, not significantly different at the 0.05 level.

Table 8. Cotton fiber quality determined by stelometer, arealometer, and high volume instrumentation (HVI) as affected by two genotypes averaged across two canopy temperature regimes (ambient and warm) and the years 2003 through 2005.

Genotype	Fiber elongation (E1)†	Fiber strength (T1)	Span length		Micronaire	Fiber maturity‡	Fiber perimeter	Length uniformity§	Rd	+b
			2.5%	50%						
	%	kN m kg^{-1}	— cm—			%	μm	—%—		
SureGrow 125	8.3	178	2.86	1.38	4.49	78.8	52.9	83.2	69.1	7.43
SureGrow 125BR	8.3	182	2.80	1.36	4.50	78.0	53.3	82.8	70.1	7.44
LSD (0.05)	ns¶	ns	0.03	ns	ns	ns	ns	ns	0.6	ns
P > *F*	0.76	0.09	0.01	0.26	0.85	0.29	0.46	0.16	0.03	0.95

†Fiber elongation, strength, span lengths, and micronaire were determined by stelometer.

‡Fiber maturity and perimeter were determined by arealometer.

§Length uniformity, Rd (reflectance %), and +b (yellowness) were determined by HVI classification.

¶ns, not significantly different at the 0.05 level.

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